P108

Development and research carbon nanotube-based resistive gas sensor

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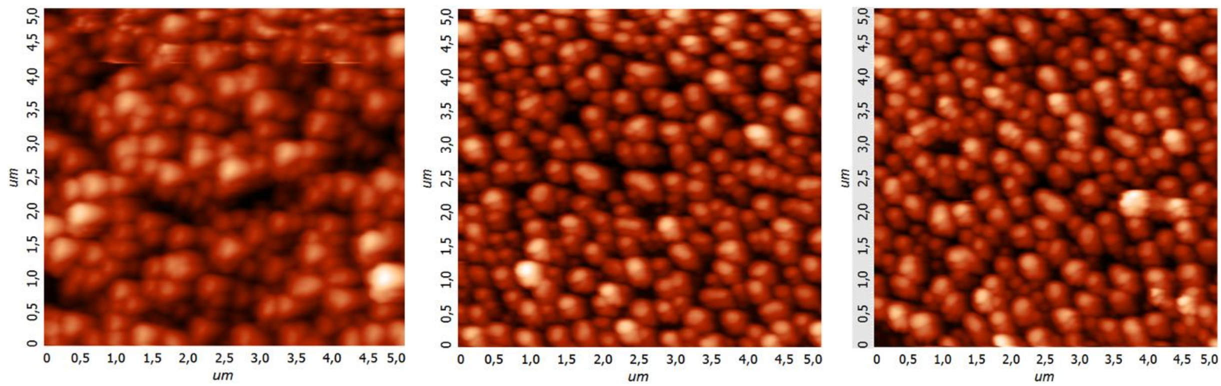
In a sophisticated man-made situation and terrorist threat dangerous one of the problems is the necessary for environmental monitoring using gas sensors. The main parameters of gas sensors are sensitivity, selectivity, response and recovery time, dimensions, power consumption. Traditional materials used in resistive sensors (SnO, ZnO, et al.) have good sensitivity, but do not show sufficient selectivity. The long reaction and recovery times, high energy consumption associated with the necessity of heating the sensitive layer [1] are the disadvantages of these sensory materials. Therefore, there is a regular research of new materials which can improve the sensors characteristics. Carbon nanotubes (CNT) are one of the most promising materials for gas sensors, which are designed to eliminate the disadvantages of sensors available on the market [2,3].

The aim of this work is the development and experimental research of the CNT-based resistive gas sensor sensitivity parameters.

The design of the sensor consists of a sitall substrate with deposited ITO (100 nm) contact layer by magnetron sputtering using a mask. Then, for the subsequent growth of a CNT-based sensitive layer, was deposited Ni catalyst film (10 nm).

A research of the effect of heating temperature on the formation of catalicyc centers (CC) for CNT growth was provide in the range of 700-800 °C. Investigation of the CC parameters of the experimental samples was carried out using a probe nanolaboratory Ntegra (NT-MDT, Russia). It is established (Fig. 1) that the temperature of 750 °C allows the formation of the smallest CC (160 ± 30 nm) with the maximum density (18 μm^{-2}).



(a) (b) (c)

Figure 1. Obtained at a temperature of: (a) 700; (b) 750; (c) 800 °C.

After, a network of disordered CNTs was grown in the NANOFAB PECVD module (Fig. 2). To investigate the work, the gas sensor was placed in a gas measuring stand, where its response to nitrogen, argon and oxygen was checked. The choice and study of the sensor's reaction to the presence of these gases is associated with their potential danger during accumulation in confined spaces.

Measurement of resistance was carried out using a universal ohmmeter B7-78/1. The sensitivity of the device was calculated by the formula:

$$S_k = \frac{R_{gas} - R_{air}}{R_{air}} \cdot 100\% \qquad (1)$$

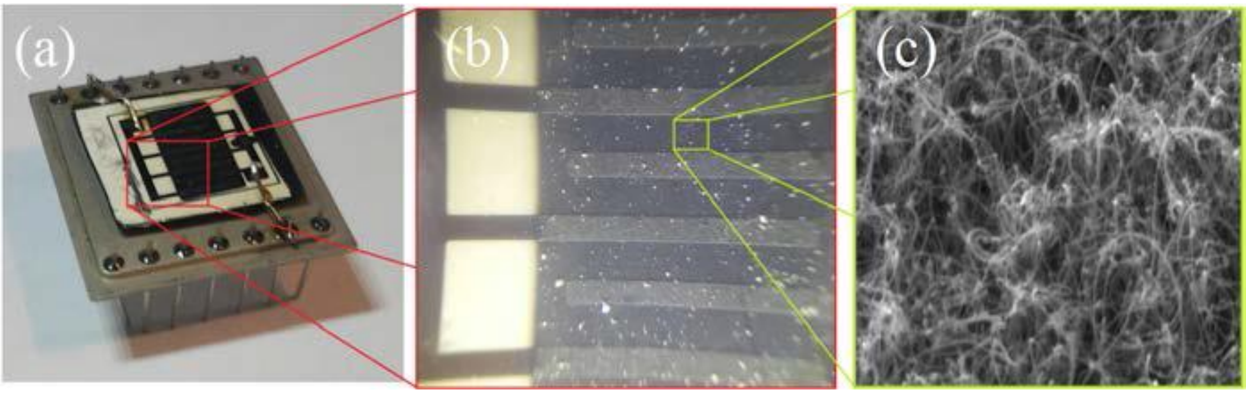
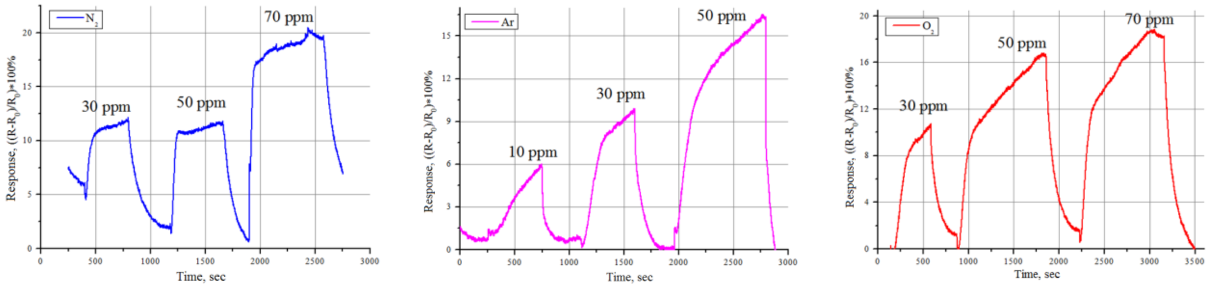


Figure 2. The model of a gas sensor: (a) side view; (b) sensitive layer with interdigital electrodes; (c) SEM-image of CNT film.

The response time was defined as a time interval of 90% of the time required for the release ($R_{gas} – R_{air}$) to a stationary level after injecting a certain concentration of the analyzed gas. Sensor recovery time was defined as the time interval during which the sensor resistance recovers after injection of the analyzed gas to 10% of the maximum value $0.1(R_{gas} – R_{air}) + R_{air}$.

The measurement of the characteristics of the sensitive element was carried out at a temperature in the measuring chamber of 300 K. The initial resistance of the structure was 516 kΩ. From the obtained results, we can conclude that the developed gas sensor sensitive element is characterized by high sensitivity and speed, a distinctive feature of which is the absence of the need to heat the sensitive element for degassing. Figure 3 shows the sensor's response to different gases.



(a) (b) (c)

Figure 3. Sensor response in the presence of gases with different concentration: (a) nitrogen; (b) argon; (c) oxygen.

Thus, the measured sensitivity to oxygen, argon, and nitrogen was 18.7%, 16.3%, and 17.2%, respectively, with a response time of 141 s, 186 s, and 153 s respectively.

Obtained results can be used in the development of promising sensor devices based on carbon nanotubes, in particular portable wearable devices as well as multisensor systems, which will expand the range of sensitivity and increase the selectivity of devices.

This work was supported by the Russian Science Foundation under grant № 18-79-00176.

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